Journal of Young Pharmacists, 2024; 16(4):653-659.
https://www.jyoungpharm.org

Review Article

Ufasomes: The Symphony of Drug Delivery

Singareddy Yasaswini, Chinthaginjala Haranath*, Lavani Firdos, Rompicharla Narasimha Sai, Turubilli Satish

Department of Pharmaceutics, Raghavendra Institute of Pharmaceutical Education and Research (RIPER)-Autonomous, Ananthapuramu, Andhra Pradesh, INDIA.

ABSTRACT

The field of ufasomes has great promise for revolutionizing drug delivery. Ufasomes have the potential to overcome limitations, enhance medicine and therapy and pave the way for future pharmacological formulations that are more effective and patient-friendly with more research and development. Ufasomes are suspensions of a closed lipid bilayer made up of fatty acids and their ionized species. They are unsaturated fatty acid vesicles with a pH range of 7-9. The primary benefit of ufasomes is that they are mostly composed of fatty acids, which allow them to readily permeate skin and exhibit systemic activity. Ufasomes demonstrate specific medication delivery. There are several kinds of preparation techniques, including vortex mixing, the autopoietic process, the round bottom flask method and thin film layer hydration. Alcohol and cholesterol are added during the preparation of ufasomes. The paper examines ufasome characteristics, pharmacokinetics, uses, advantages, disadvantages and applications. These vesicles have uses in nutrition encapsulation, drug delivery and cosmetic development.

Keywords: Ufasomes, Unsaturated fatty acids, Thin film layer hydration, Autopoietic process.

Correspondence:
Dr. Chinthaginjala Haranath
Associate Professor and Head,
Department of Pharmaceutics,
Raghavendra Institute of Pharmaceutical Education and Research (RIPER),
Anantapuramu, Andhra Pradesh, INDIA.
Email: haranathriper@gmail.com

Received: 21-05-2024;
Revised: 09-06-2024;
Accepted: 19-07-2024.

INTRODUCTION

Paul Ehrlich developed the target drug delivery approach in 1909, which entails administering target drugs directly to damaged cells.[1] The vesicular drug delivery system is a novel approach to delivering drugs at precise sites. These show that treatments work where they are supposed to while avoiding negative side effects.[2] Vesicular drug delivery systems are especially useful for targeted drug delivery because they can localize the drug's activity at the site of organ or action, reducing its concentration elsewhere in the body, delaying the removal of medications that metabolize quickly and functioning as sustained-release systems.

The vesicular drug delivery mechanism produces the liposome, transferosome, neosome, phytosome and ufasome.[3] Liposomes are a kind of concentric, colloidal bilayer vesicles, totally enclosed in a bilayer membrane and mostly composed of lipids, either synthetic or natural, in their aqueous compartment. Liposomes are composed of phospholipids, while ufasomes are mostly composed of fatty acids.[4] To improve the stratum corneum's capacity to absorb medications into the skin, ufasomes were created. Ufasomes have a lipid carrier that sticks to the skin's surface and makes it easier for lipids to move from the stratum corneum to the skin's outermost layer.[5]

Suspensions of a closed lipid bilayer composed of ionized species of fatty acids are known as ufasomes. Their pH ranges from 7-9, making them unsaturated fatty acid vesicles.[6] Ufasomes, which are long-chain unsaturated fatty acid vesicles, are created when an evaporated film is physically stirred in the presence of a buffer solution.[7] Ufasomes represent a groundbreaking approach to vesicular drug delivery in the future. They are more stable than liposomes and have higher entrapment efficiency for both hydrophilic and hydrophobic drugs. They are less expensive than liposomes.[8] One of the primary benefits of ufasomes over liposomes is their availability of fatty acids.[9] Ufasomes lengthen a drug's half-life in the blood and lessen its toxicity. The drug can be absorbed selectively since it is delivered directly to the source.[10,11] Improves bioavailability, especially for those having difficulty dissolving medications. Drugs that are lipophilic or hydrophilic can be incorporated into ufasomes.

As ufasomes may encapsulate both hydrophilic and hydrophobic medicines, they are used as a drug delivery mechanism. They are also biocompatible and biodegradable.[12] Fatty acid molecules' carboxyl groups come into contact with water in ufasomes, but their hydrocarbon tails are directed into the interior of the membrane. They can function as medication transporters as a result of this.[13]

Fatty acid vesicles are created when ionized fatty acids are dispersed colloidally. When synthesizing ufasomes, unsaturated fatty acids like oleic and linoleic acids are used as natural permeability enhancers.[14] One of the primary advantages of ufasomes over liposomes is the easy availability of fatty acids.[15]

OPEN ACCESS

Manuscript TECHNOMEDIA

DOI: 10.5530/jyp.2024.16.83

Copyright Information :
Copyright Author (s) 2024 Distributed under Creative Commons CC-BY 4.0

Publishing Partner : Manuscript Technomedia. [www.mstechnomedia.com]

In order to increase skin suppleness and enhance medicine dispersion across the skin membrane, fatty acids and surfactants are frequently used. Ufasomes have long improved skin cell membranes' capacity to hold onto drugs. The ufasome is composed of fatty acid vesicles. The direction of the carboxyl groups in contact with water and the membrane fatty acid hydrocarbon tails toward the membrane's interior produce the bilayer structure.[16] Ufasomes are soapy suspensions of closed lipid bilayers, mostly made up of fatty acids. Their pH is typically maintained between 7 and 9.

Advantages

- Unlike liposomes, ufasomes are more stable.
- For both hydrophilic and hydrophobic medicines, ufasomes show improved entrapment efficiency.[17]
- Ufasomes are less expensive than liposomes.[18]
- Ufasomes can be used as oral delivery systems for drugs that are less soluble.[19]
- When applied topically, the medication readily permeates the skin.[20]
- A possible method of administering anti-inflammatory medications.[21]

Disadvantages

- Ufasomes easily oxidize, which causes issues with stability in fatty medication preparations.
- Certain byproducts of oxidation may be harmful.[22]
- Ufasomes' colloidal instability prevents them from being used as food additives or drug delivery systems.
- Risk of atherosclerosis.

REQUIREMENTS, STRUCTURE AND COMPOSITION

Ufasomes are composed of the following components and their specific function, description was given in Table 1 and the structure of ufasomes is described in Figure 1.[23-35]

COMPREHENSIVE WAY OF FORMATION

Materials that are not oxidized are used to create ufasomes. Oleic and linoleic acid stock solutions are made and kept at 20°C. Chloroform has 10% of each acid. For standard preparations, 0.02 mL of the stock solution is evaporated in a test tube using a water pump. The solution is then sprayed with nitrogen to dry it off. The solvent most commonly employed to make ufasomes is trichlorohydroxymethyl aminomethane; however, buffers like borate, glycine-hydroxide and bicarbonate solutions can also be effective. The fatty acid composition, cholesterol level, pH range, buffer and lipoxygenase quantity are the main factors that affect the formation of stable ufasomes.[36] Ufasomes are lipid-based vesicular systems that may be used to encapsulate and distribute a wide range of materials, including vitamins, medications and chemicals for cosmetics. They are made by combining lipids and surfactants to create vesicles that self-assemble.

PHARMACOKINETICS OF UFASOMES

Absorption

Oral Administration

The acidic stomach environment makes ufasomes less stable, which can cause them to break down too soon. Using pH-sensitive formulations or enteric coatings are two methods to increase stability.

Parenteral injection

Bypassing the digestive tract, Intravenous (IV) injection of ufasomes results in improved bioavailability and a speedier therapeutic impact.[37]

Distribution

Circulation

The Reticuloendothelial System (RES), which has the ability to remove ufasomes from circulation and the ufasomes' interactions with plasma proteins determine their distribution within the body.[38]

Targeting

Surface alterations can improve targeting to particular cells or tissues. By lessening immune system detection and clearance, PEGylation-the addition of polyethylene glycol-can lengthen the period of circulation.[39]

Tissue Penetration

Ufasomes' capacity to enter tissues and absorb cellular contents is influenced by their size, charge and surface characteristics.

Metabolism

Biodegradation

The body's natural lipid metabolic pathways break down ufasomes made of fatty acids.

Lipid Metabolism

Fatty acids can be further broken down into smaller components by enzymes such as lipases, allowing the body to use or metabolize them further.[40]

Excretion

Renal Clearance

The kidneys can filter small breakdown products of ufasomes, like free fatty acids and excrete them in urine.

Biliary Excretion

If certain lipid constituents are converted into bile acids or other lipid-soluble metabolites, they may be eliminated through the bile.

Table 1: Components of ufasomes.

Components	Function and Description
Phospholipids	Lipid bilayer building components.[23]
Unsaturated fatty acids	Ingredients for encapsulation that are active.[24]
Cholesterol	Controls membrane fluidity.[25]
Stabilizers	Improves stability.[26]
Surfactants	increases dispersibility and stability.[27]
Polymers	Improve structural integrity.[28]
Solvents and excipients	Contributes to the production of ufasomes.[29]
Surface-modifying agents	Controls membrane fluidity.[30]
Co-solvents	Improve solubility.[31]
Organic solvents	Dissolve lipids and Ufasomes.[32]
PEG (Polyethylene Glycol)	Increase circulation time.[33]
Buffer solutions	Controls pH.
Ligands, e.g., antibodies	Enable targeted delivery.[34]
Antioxidants	Protects from oxidation.[35]

FACTORS AFFECTING PHARMACOKINETICS

Vesicle Size and Composition

Larger vesicles may circulate longer and be removed more quickly than smaller ones. The stability and metabolism of ufasomes might be affected by the fatty acids included in the formulation.

Surface Modifications

By modifying circulation time and targeting capabilities, PEGylation and targeting ligands can change the pharmacokinetic profile.

Administration and Dosage Route

Pharmacokinetics is greatly impacted by the route of administration. When opposed to oral approaches, IV treatment offers a more direct and controlled delivery.[41]

UFASOMAL GELS

Gel matrices and ultra flexible liposomes (ufasomes) are combined in ufasomal gels, a novel drug delivery technology that improves drug stability and penetration. Because of their flexibility, ufasomes can penetrate the skin more effectively and the gel matrix allows for regulated release. These gels work well for transdermal and topical applications, enhancing the prolonged release and bioavailability of medications. Benefits of pharmacokinetics include improved absorption, systemic and localized distribution, decreased metabolism at the location and extended duration of action. In the realms of cosmetics and pharmaceuticals, they provide noteworthy therapeutic benefits.[42,43]

METHODS OF PREPARATION OF UFASOMES

Thin Film Hydration Method

Prepare the lipid and surfactant mixture in an organic solvent,[44] evaporate with a rotary evaporator or nitrogen stream to cover the flask walls. To eliminate remaining solvent, lower the pressure

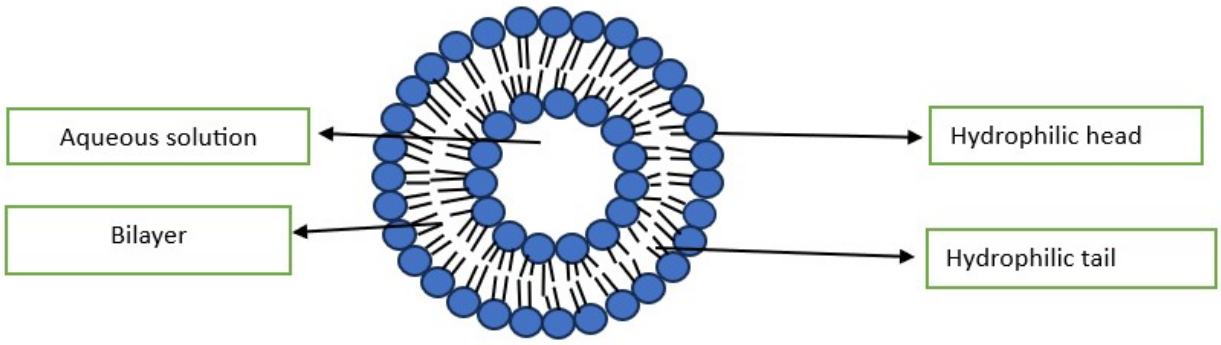

Figure 1: Structure of ufasomes.

overnight.[45] Rehydrate the lipid film with an aqueous solution of the appropriate component to ensure vesicle fusion. Optionally, further treat ufasomes to ensure uniform size distribution.

Reverse Phase Evaporation Method

To generate an oil phase, dissolve lipids and surfactants in organic solvent; then, prepare an aqueous phase containing the desired component. Combine all phases to produce an emulsion, then evaporate the solvent under low pressure to generate a water-oil emulsion.[46] To create a thick gel-like consistency, add water solution, homogenize and vortex.[47,48] Allow the system to acclimate for vesicle production before performing additional processing processes such as sonication or extrusion to ensure size and homogeneity.[49]

Vortex mixing

By using this method, a stock of 10% oleic and linoleic acid in chloroform at 200°C is produced and kept fresh. The 0.2 mL of this stock solution in a test tube is dried with a nitrogen stream to produce a film after being allowed to evaporate on a water pump. When 0.2 mL of 0.1 M Tris-hydroxymethyl aminomethane buffer with a pH of 8-9 is added, the resulting fatty acid coating is totally eliminated, yielding a ufasome solution.

By adding alcohol

In this novel manner, alcohol, which has the same chain length as fatty acids, is added to promote the formation of vesicles. Over a wide pH range, this technique produces very stable unsaturated fatty acid vesicles. This is a laborious process. This laborious procedure is prevented in part by the matrix effect, which offers helpful support all throughout the production process. This technique entails increasing the rate of vesicle synthesis using pre-added fatty acid vesicles in the system.

By the autopoietic process

When an aqueous solution containing fatty acids is introduced to a solution that has been water-bubbled, fatty acid vesicles are produced. This pH change happens on its own. The formation of vesicles is often observed when half of the fatty and carboxylic acids ionize. Unlike the aqueous compartment, the hydrocarbon chain is wrapped in a bilayer structure that decreases the chain's interaction with the water.

It's crucial to keep in mind that the specific ratios, manufacturing processes and composition could vary depending on the desired applications and characteristics of the ufasomes.

CHARACTERIZATION OF UFASOMES

Particle size and size distribution

The average diameter and size distributions of ufasome suspensions at a fixed angle of 90 degrees and a temperature of 25°C are evaluated using photon correlation spectroscopy in a particle size analyser. The suspensions were diluted with phosphate buffer and then passed over a polycarbonate membrane (pH 7.4). As a result, particulate matter interference is lessened at the size level.

Shape and morphology

Transmission Electron Microscopy (TEM) is one method to examine the sphericity and accumulation of drug-loaded ufasomal dispersion. One drop of the chosen ufasomal dispersion can be examined and negatively stained with 1% phosphotungstic acid on a copper grid covered in carbon film. Prior to TEM inspection, the sample must dry for 10 min at room temperature.

Entrapment Efficacy

The percentage of medication that is delivered that is trapped by ufasomes is known as entrapment efficiency, or EE%. It is possible to remove unencapsulated, free medicine from the solution by using ultracentrifugation or dialysis. One may observe the supernatant using UV spectroscopy.[50,51]

To determine the proportion of medication that is entrapped, apply the following equation:

Entrapment effectiveness=total amountx100 entrapped amount

The stability of pH

To investigate the effects of pH on stability and drug release activity, buffers with pH values of 8.5, 7.4, 6.5 and 5.5 were incubated with optimum vesicular dispersion.[14] Samples are obtained at predetermined intervals and centrifuged at 14,000 rpm for 30 min. The supernatant can be used to test the free medication. To determine how much medicine has leached, use the method described below.

% drug diffused=free drug amount/total drug 100

In vitro drug release

This study aims to assess the ufasome release kinetics and rate of the medication. Franz diffusion cells might be used to do this. Two compartments make up the Franz diffusion cell: a donor compartment and a receptor compartment. There is a porous polycarbonate membrane, 50 nm in size, separating these two compartments. 1 mL of ufasomal dispersion was present in the donor compartment, while PBS with a pH of 7.4 was kept in the receptor compartment and constantly agitated at 37°C using a magnetic stirrer. Aliquots of the samples are taken on a regular basis and swapped out by comparable volumes of brand-new PBS (pH 7.4).

Zeta Potential-Charge Repulsion Analysis

The degree of charge, electrostatic repulsion, or attraction between particles is measured by the zeta potential. The zeta potential is affected by the properties of the liquid as well as the particles.[52] It is crucial for figuring out the aggregative stability of

the solution or emulsion. With larger zeta potentials, the system is more stable and the repulsion is stronger.

Photo Microscopy

For the purpose of vesicle organization and morphology, vesicle scattering was seen using photographic microscopy. An optical magnifying lens and a camera with an amplification range of 40 to 100 x 11 were used to investigate ufasomal suspensions.

RECENT INNOVATIONS

New fatty acid types

Cis-4, 7, 10, 13, 16 and 19-Docosahexaenoic Acid (DHA) spontaneously forms vesicles at pH values between 8.5 and 9. This offers another fatty acid substitute for ufasome production, expanding the scope of possible uses.

Extension of the pH range

The need for carboxylic acid ionization frequently restricts the pH range across which vesicles made from fatty acids may be produced. Recent developments have extended this pH range in a number of ways:

Amphiphilic Additives

In atypical pH settings, vesicle production is stimulated by adding linear alcohols or surfactants with sulfate or sulfonate head groups to fatty acids. For example, these compounds can be combined with decanoic acid to reduce the required pH for vesicle production to 4.3.

Synthetic Head Group Modification

Lower pH levels improve vesicle stability when an oligo (ethylene oxide) unit is inserted between the fatty acids carboxylate head group and hydrocarbon chain. This alteration impacts the phase transition temperature as well as the pH range where vesicles form.

Divalent cation sensitivity

Ufasomes are typically associated with divalent cations such as Mg2+ and Ca2+, which can precipitate vesicles even in trace amounts. Recent advances have employed fatty acid glycerol esters to stabilize ufasomes in the presence of these cations, enhancing their stability and applicability for a variety of uses.

Cristiano MC, *et al*, developed ufasomes can supply oleuropein while enhancing antioxidant activity and cell-nano system interaction. Oleuropein and unsaturated fatty acids can be combined to achieve these goals.[53]

Hashem SM, *et al*, study indicate that ITZ-loaded ufasomes have the potential to cure Candida albicans infections by downregulating immunomodulatory markers and inhibiting important enzymes.[54]

Bhattacharya S. *et al*, examined entrapment efficacy, drug-to-lipid ratio and size. Glyceryl oleate ufasomes improved skin penetration and showed strong antifungal action against cutaneous candidiasis in rats. To increase the stability of cationic ufasomes, more study is required.[55]

PHARMACEUTICAL APPLICATIONS OF UFASOMES

Anti-cancer

5-Fluorouracil (5-FU) is used topically to treat basal cell carcinoma; however typical formulations can cause eczema and redness. Ufasomes, or fatty acid vesicles, encapsulate 5-FU, allowing it to penetrate the epidermal layer while decreasing side effects and boosting therapeutic efficacy.[56]

Anti-inflammatory

Ufasomes, which carry anti-inflammatory medications like dexamethasone, have shown potential in lowering inflammation, notably in rheumatoid arthritis. They provide better drug delivery than traditional formulations, possibly altering treatment approaches for inflammatory illnesses such as psoriasis through increased skin penetration and targeted administration.

Anti-fungal

Ufasomes loaded with antifungal drugs like terbinafine hydrochloride and oxiconazole demonstrate enhanced skin penetration and systemic absorption compared to traditional creams and gels, vital for treating deep fungal infections including those caused by Candida albicans. Adjusted ufasomal formulations exhibit increased effectiveness, as indicated by a larger zone of inhibition, highlighting their potential for more efficient antifungal therapy.[57]

Anti-osteoarthritic

Because of their excellent entrapment effectiveness, glucosamine-sulfate-loaded ufasomes offer a viable treatment for osteoarthritis by quickly encapsulating and delivering medication. With established continuous drug release *in vitro*, these vesicles are a viable option for topical delivery, potentially allowing for long-term symptom relief and management of osteoarthritis.

Other Pharmaceutical Applications

Ufasomes are used in a variety of medical and cosmetic applications, including the treatment of hair loss with minoxidil and the enhancement of antioxidant capabilities in products such as Oleuropein. Their diversity demonstrates their efficacy in treating a variety of medical and aesthetic conditions.

Transdermal Hormone Replacement

Ufasomes provide an effective delivery mechanism for transdermal hormone replacement treatment, delivering

hormones such as Estrogen and progesterone to postmenopausal women. This approach ensures regulated hormone distribution through the skin, eliminating the need for oral medication and lowering systemic side effects.[58]

Pain Management

Ufasomes, containing analgesic pharmaceuticals like lidocaine and diclofenac, revolutionize pain management. Lidocaine-loaded ufasomes target regional pain effectively,[59] while diclofenac-loaded ones offer localized anti-inflammatory relief, minimizing systemic side effects.[60]

Vitamins and antioxidants

Ufasomes enriched with Vitamins C and E improve skincare formulations by offering powerful antioxidants and UV protection. Vitamin C ufasomes stimulate collagen formation, reduce oxidative stress and brighten skin, whereas vitamin E ufasomes protect the skin from damaging UV rays and improve general skin health.[61]

Anti-viral Medications

Ufasomes containing antiviral medicines, such as acyclovir, show potential in treating viral skin diseases like herpes. Targeted administration improves efficacy while reducing systemic exposure, allowing for effective control of herpes outbreaks via skin penetration.[62,63]

Topical Antibiotics

Ufasomes deliver antibiotics such as clindamycin for localized skin infections, reducing systemic exposure and the possibility of resistance while providing tailored treatment.

Anti-Wrinkle Treatments

Ufasomes containing peptides and retinoids provide targeted anti-aging advantages in cosmetics, with retinoid-loaded ones specifically targeting fine lines and wrinkles. Encapsulation ensures regulated release, boosting efficacy in revitalizing aged skin.[64]

Acne Medications

Ufasomes enable the transdermal administration of salicylic acid-based acne medicines, improving their efficacy in acne treatment. Ufasomes, which contain salicylic acid, promote penetration to effectively treat acne while minimizing skin irritation.[65]

CONCLUSION

Ufasomes are the future of drug administration. They have the potential to improve the way drugs work. However, there are several obstacles to overcome. Still, the prospect of ufasomes making drugs more effective, safer and tailored is very appealing. Scientists are working hard to discover all of the great things that ufasomes can perform.

ACKNOWLEDGEMENT

The authors are thankful to the Raghavendra Institute of Pharmaceutical Education and Research for provided support.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. Ghumare A, Talele S, Chaudhary A, Kothawade A, Pawar R, Jadhav A. Niosome: A promising novel drug delivery system for the natural drug through blood brain barrier. World J Pharm Res. 2020;9:674-86.
2. Sarvarian P, Samadi P, Gholipour E, Shams Asenjan K, Hojjat-Farsangi M, Motavalli R, et al. Application of emerging plant-derived nanoparticles as a novel approach for nano-drug delivery systems. Immunol Investig. 2022;51(4):1039-59. doi: 10.1080/08820139.2021.1891094, PMID 33627016.
3. Myneni GS, Radha G, Soujanya G. Novel vesicular drug delivery systems: a review. J Pharm Res. 2021;11:1650-64.
4. Zoabi A, Touitou E, Margulis K. Recent advances in nanomaterials for dermal and transdermal applications. Colloids Interfaces. 2021;5(1):18. doi: 10.3390/colloids5010018.
5. Williams A. Controlled drug delivery into and through skin. Fundam Drug Deliv. 2021:507-34.
6. Patel H. A vesicular drug delivery for futuristic drug delivery applications: ufasomes. Indian J Pharm Biol Res. 2022;10(04).
7. Gautam R, Gautam D, Pandit V, Ashawat M. ufasomes: an Overall Review on Drug Delivery Carrier. 2022;14(6):24-9.
8. Nayak AK, Hasnain MS, Aminabhavi TM, Torchilin VP. Nanovesicular systems in drug delivery. Systems of Nanovesicular drug delivery. Elsevier; 2022. p. 1-15.
9. Lakshmi VS, Manohar RD, Mathan S, Dharan SS. Formulation and evaluation of ufasomal topical gel containing selected non-steroidal anti-inflammatory drug (NSAIDs). J Pharm Sci Res. 2021;13(1):38-48.
10. Shinde NG, Aloorkar NH, Kulkarni AS. Recent advances in vesicular drug delivery system. Res J Pharm Dosage Forms Technol. 2014;6(2):110-20.
11. Attia MS, Abdel-Mottaleb MS, Mohamed EH. Smart nanovesicles for drug delivery. Syst Nanovesicular Drug Deliv. 2022;2(1):367-85.
12. Sharma R, Dua JS, Prasad D, Hira S. Advancement in novel drug delivery system: niosomes. J Drug Deliv Ther. 2019; 9(3-s):995-1001.
13. Nagasa GD, Belete A. Review on nanomaterials and nano-scaled Systems for Topical and Systemic Delivery of antifungal drugs. J Multidiscip Healthc. 2022;15:1819-40. doi: 10.2147/JMDH.S359282, PMID 36060421.
14. Lakshmi VS, Manohar RD, Mathan S, Dharan SS. Ufasomes: A potential vesicular carrier system. J Pharm Sci Res. 2020;12(10):1332-5.
15. Luke PM, Ufasomes JT. Rising technology for delivery of drugs. Int J Med Pharm Sci;2021: 11(11):1.
16. Zafar A, Ahmed N. Nanovesicles for target specific drug delivery. Applications of Nanovesicular drug delivery. Elsevier; 2022. p. 149-65.
17. Liu H, Hu X, Li L, Meng X, Fang Y, Xia Y. Micron and nano hybrid ufasomes from conjugated linoleic acid, their vesiculation and encapsulation of ginsenoside Rg3. J Sci Food Agric. 2022;102(10):4140-50. doi: 10.1002/jsfa.11763, PMID 34997612.
18. Cristiano MC, Froiio F, Mancuso A, Cosco D, Dini L, Di Marzio L, et al. Oleuropein-laded ufasomes improve the nutraceutical efficacy. Nanomaterials (Basel). 2021;11(1):105. doi: 10.3390/nano11010105, PMID 33406805.
19. Arundhasree R, Aiswarya R, Kumar A, Kumar AR, Kumar SS, Nair SC. Ufasomes: unsaturated fatty acid based vesicular drug delivery system. Int J Appl Pharm. 2021;13(2):76-83. doi: 10.22159/ijap.2021v13i2.39526.
20. Alenzi AM, Albalawi SA, Alghamdi SG, Albalawi RF, Albalawi HS, Qushawy M. Review on different vesicular drug delivery systems (VDDSs) and their applications. Recent Pat Nanotechnol. 2023;17(1):18-32. doi: 10.2174/1872210516666220228150624, PMID 35227188.
21. Atef B, Ishak RA, Badawy SS, Osman R. Exploring the potential of oleic acid in nanotechnology-mediated dermal drug delivery: an up-to-date review. J Drug Deliv Sci. 2022;67:103032. doi: 10.1016/j.jddst.2021.103032.
22. Cristiano MC, Froiio F, Mancuso A, Cosco D, Dini L, Di Marzio L, et al. Oleuropein-laded ufasomes improve the nutraceutical efficacy. Nanomaterials (Basel). 2021;11(1):105. doi: 10.3390/nano11010105, PMID 33406805.
23. Wang X, Du H, Wang Z, Mu W, Han X. Versatile phospholipid assemblies for functional synthetic cells and artificial tissues. Adv Mater. 2021;33(6):2002635. doi: 10.1002/adma.202002635, PMID 32830387.

24. Du Q, Zhou L, Li M, Lyu F, Liu J, Ding Y. Omega-3 polyunsaturated fatty acid encapsulation system: physical and oxidative stability and medical applications. Food Front. 2022;3(2):239-55. doi: 10.1002/fft2.134.
25. Korinek M, Gonzalez-Gonzalez IM, Smejkalova T, Hajdukovic D, Skrenkova K, Krusek J, et al. Cholesterol modulates presynaptic and postsynaptic properties of excitatory synaptic transmission. Sci Rep. 2020;10(1):12651. doi: 10.1038/s41598-020-69454-5 , PMID 32724221.
26. Guimarães D, Cavaco-Paulo A, Nogueira E. Design of liposomes as drug delivery system for therapeutic applications. Int J Pharm. 2021;601:120571. doi: 10.1016/j.ijpharm.2021.120571, PMID 33812967.
27. Shaban SM, Kang J, Kim DH. Surfactants: recent advances and their applications. Compos Commun. 2020;22:100537. doi: 10.1016/j.coco.2020.100537.
28. Naskar P, Maiti A, Chakraborty P, Kundu D, Biswas B, Banerjee A. Chemical supercapacitors: a review focusing on metallic compounds and conducting polymers. J Mater Chem A. 2021;9(4):1970-2017. doi: 10.1039/D0TA09655E.
29. Shetty K, Sherje AP. Nano intervention in topical delivery of corticosteroid for psoriasis and atopic dermatitis-a systematic review. J Mater Sci Mater Med. 2021;32(8):88. doi: 10.1007/s10856-021-06558-y, PMID 34331599.
30. Yang X, Wan Y, Zheng Y, He F, Yu Z, Huang J, et al. Surface functional groups of carbon-based adsorbents and their roles in the removal of heavy metals from aqueous solutions: a critical review. Chem Eng J. 2019;366:608-21. doi: 10.1016/j.cej.2019.02.119, PMID 34522159.
31. Li G, Zhou D, Xu QQ, Qiao GY, Yin JZ. Effect of different co-solvents on solubility of ILs [Emim] Ac,[Bmim][NTf2] in ScCO2. J Mol Liq. 2019;284:102-9. doi: 10.1016/j.molliq.2019.03.174.
32. Kaur M, Kaur L, Singh G, Singh L, Kaur A, Dhawan RK. Recent advancements in biomimetic drug delivery system of single-chain fatty acids as ufasomes and Ufosomes: A comprehensive review. Curr Nanosci. 2023;19(3):362-71. doi: 10.2174/1573413718666220919113148.
33. Hoang Thi TT, Pilkington EH, Nguyen DH, Lee JS, Park KD, Truong NP. The importance of poly (ethylene glycol) alternatives for overcoming PEG immunogenicity in drug delivery and bioconjugation. Polymers. 2020;12(2):298. doi: 10.3390/polym12020298, PMID 32024289.
34. Prabahar K, Alanazi Z, Qushawy M. Targeted drug delivery system: advantages, carriers and strategies. Indian J Pharm Educ. 2021;55(2):346-53. doi: 10.5530/ijper.55.2.72.
35. Adwas AA, Elsayed A, Azab A, Quwaydir F. Oxidative stress and antioxidant mechanisms in human body. J Appl Biotechnol Bioeng. 2019;6(1):43-7.
36. Patel D, Patel C, Jani R. Ufasomes: a vesicular drug delivery. Syst Rev Pharm. 2011;2(2):72. doi: 10.4103/0975-8453.86290.
37. Sreeharsha N, Philip M, Krishna SS, Viswanad V, Sahu RK, Shiroorkar PN, et al. Multifunctional mesoporous silica nanoparticles for oral drug delivery. Coatings. 2022;12(3):358. doi: 10.3390/coatings12030358.
38. Aiswarya MU, Raju K, Menon RB, Lakshmi VS, Nair SC. Cryptosomes: a revolutionary breakthrough in novel drug delivery. Int J Appl Pharm. 2019;11(7).
39. Hussain Z, Khan S, Imran M, Sohail M, Shah SW, de Matas M. PEGylation: a promising strategy to overcome challenges to cancer-targeted nanomedicines: a review of challenges to clinical transition and promising resolution. Drug Deliv Transl Res. 2019;9(3):721-34. doi: 10.1007/s13346-019-00631-4, PMID 30895453.
40. Alenzi AM, Albalawi SA, Alghamdi SG, Albalawi RF, Albalawi HS, Qushawy M. Review on different vesicular drug delivery systems (VDDSs) and their applications. Recent Pat Nanotechnol. 2023;17(1):18-32. doi: 10.2174/1872210516666220228150624, PMID 35227188.
41. Ahmad Z, Harsha S, Parray A, et al. Sustained release of drugs via ufasomal gels: a review. J Control Release. 2019;310:244-56.
42. Li N, Zhuang C, Wang M, Sun X, Nie S, Pan W. Development and evaluation of a novel ultraflexible liposomal gel for topical delivery. Int J Pharm. 2021;594:120161.
43. Shaker DS, Younes HM, Elkamel A, et al. Ultraflexible liposomal gel: a promising topical and transdermal drug delivery system. Pharm Dev Technol. 2022;27(5):601-14.
44. Paudwal G, Banjare N, Gupta PN. Nanovesicles for nasal drug delivery. Applications of Nanovesicular drug delivery. Elsevier; 2022. p. 81-101.
45. Lombardo D, Kiselev MA. Methods of liposomes preparation: formation and control factors of versatile nanocarriers for biomedical and nanomedicine application. Pharmaceutics. 2022;14(3):543. doi: 10.3390/pharmaceutics14030543, PMID 35335920.
46. Gutiérrez-Méndez N, Chavez-Garay DR, Leal-Ramos MY. Lecithins: A comprehensive review of their properties and their use in formulating microemulsions. J Food Biochem. 2022;46(7):14157. doi: 10.1111/jfbc.14157, PMID 35355280.
47. Yeo LK. Evaluation of niosome formulations containing methylene blue and cinnarizine manufactured by thin film hydration and microfluidic methods. University of Sunderland; 2022.
48. Patil A, Jain G, Iliger SR, Nagar M, Ranjan N, Kar SM, et al. Formulation, characterisation and pharmacokinetics of felodepine navovesicles for transdermal drug delivery system. J Cardiovasc Dis Res. 2023;14(7):85-105.
49. Köster DV, Bhat A, Talluri S, Mayor S. Reconstitution of membrane-tethered minimal actin cortices on supported lipid bilayers. J Vis Exp. 2022;(185):63968. doi: 10.3791/63968, PMID 35913196.
50. Hashem SM, Gad MK, Anwar HM, Saleh NM, Shamma RN, Elsherif NI, et al. Evaluation, characterization and anti-fungal activity against Candida albicans. Pharmaceutics. 2022;15(1):26.
51. Abedin S, Karimi M, rezaeilaal A, Jafariazar Z, Afshar M. Formulation, in vitro and ex vivo evaluation of albendazole loaded ufasomal nanoformulation for topical delivery. J Drug Deliv Sci Technol. 2022;76:103726. doi: 10.1016/j.jddst.2022.103726.
52. de Souza AG, de Lima GF, Colombo R, Rosa DS. A new approach for the use of anionic surfactants: nanocellulose modification and development of biodegradable nanocomposites. Cellulose. 2020;27(10):5707-28. doi: 10.1007/s10570-020-03160-3.
53. Cristiano MC, Froiio F, Mancuso A, Cosco D, Dini L, Di Marzio L, et al. Oleuropein-laded ufasomes improve the nutraceutical efficacy. Nanomaterials (Basel). 2021;11(1):105. doi: 10.3390/nano11010105, PMID 33406805.
54. Hashem SM, Gad MK, Anwar HM, Saleh NM, Shamma RN, Elsherif NI, et al. Evaluation, characterization and anti-fungal activity against Candida albicans. Pharmaceutics. 2022;15(1):26.
55. Bhattacharya S. Preparation and characterizations of glyceryl oleate ufasomes of terbinafine hydrochloride: A novel approach to trigger Candida albicans fungal infection. Future J Pharm Sci. 2021;7:1.
56. Saindane D, Bhattacharya S, Shah R, Prajapati BG. The recent development of topical nanoparticles for annihilating skin cancer. All life. 2022;15(1):843-69.
57. Nene S, Shah S, Rangaraj N, Mehra NK, Singh PK, Srivastava S. Lipid based nanocarriers: A novel paradigm for topical antifungal therapy. J Drug Deliv Sci Technol. 2021;62:102397. doi: 10.1016/j.jddst.2021.102397.
58. Ahmed YM, Orfali R, Hamad DS, Rateb ME, Farouk HO. Sustainable Release of propranolol hydrochloride Laden with Biconjugated-Ufasomes chitosan Hydrogel Attenuates Cisplatin-Induced sciatic nerve Damage in in vitro/in vivo Evaluation. Pharmaceutics. 2022;14(8):1536. doi: 10.3390/pharmaceutics14081536, PMID 35893792.
59. Stefanov SR, andonova VY. Lipid nanoparticulate drug delivery systems: recent advances in the treatment of skin disorders. Pharmaceuticals (Basel). 2021;14(11):1083. doi: 10.3390/ph14111083, PMID 34832865.
60. Gorde N, Waghulde SO, Kharche A, Kale M. Vesicular drug delivery in arthritis treatment. Adv Novel Formul Drug Deliv. 2023:177-95.
61. Van Tran V, Moon JY, Lee YC. Liposomes for delivery of antioxidants in cosmeceuticals: challenges and development strategies. J Control Release. 2019;300:114-40. doi: 10.1016/j.jconrel.2019.03.003, PMID 30853528.
62. Radwan Y, Karaly AH, El-Sherbiny IM. Nanovesicles for delivery of antiviral agents. Viral infections and antiviral therapies. Elsevier; 2023. p. 493-518.
63. Pattnaik S, Swain K, Singh SP, Sirbaiya AK. Lipid vesicles: potentials as drug delivery systems. Nanoengineered biomaterials for advanced drug delivery. Elsevier; 2020. p. 163-80.
64. Chime A, Onyishi IV. Lipid-based drug delivery systems (LDDS): recent advances and applications of lipids in drug delivery. Afr J Pharm Pharmacol. 2013;7(48):3034-59. doi: 10.5897/AJPPX2013.0004.
65. Shabbir M, Nagra U, Zaman M, Mahmood A, Barkat K. Lipid vesicles and nanoparticles for non-invasive topical and transdermal drug delivery. Curr Pharm Des. 2020;26(18):2149-66. doi: 10.2174/1381612826666200114090659, PMID 31931691.

Cite this article: Yasaswini S, Haranath C, Firdos L, Sai RN, Satish T. Ufasomes: The Symphony of Drug Delivery. J Young Pharm. 2024;16(4):653-9.